**Summary of Research**

NASA-Ames Cooperative Agreement Number NCC 2-705

# Investigation of the Microphysics and Dynamics of Stratosphere-Troposphere Exchange Processes

For the period February 1, 1991 through January 31, 1996

Submitted to
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## Research Goals

The original purpose of this research was to investigate the microphysics and dynamics of stratosphere-troposphere exchange processes, with an overall view towards improving our understanding of the transport of mass and trace constituents into and through the stratosphere. Within the scope of the latter goal, the research activities have been expanded over the course of the Cooperative Agreement to include investigations of large-scale transport processes in the stratosphere as a whole. The goal here was to identify the processes which transport air masses within the lower stratosphere, particularly between the tropics and middle latitudes. The research program has also been augmented by participation in field missions in which data used in these studies is gathered.

## Accomplishments

The Stratosphere-Troposphere Exchange Project (STEP) tropical mission in Darwin, Australia in January and February 1987 provided the focus for diagnostic studies of stratosphere-troposphere exchange processes at the tropical tropopause. A principal finding from this work, discussed in Dr. Selkirk's contribution to the 1993 STEP special section in the Journal of Geophysical Research, is the elevation of the tropopause potential temperature above the local maximum value of the surface equivalent potential temperature. This was unambiguous evidence that stratosphere-troposphere exchange did indeed occur as a consequence of the deep convection in the Australian monsoon.

The microphysical investigations have involved diagnostic and modeling studies in collaboration with Drs. Eric Jensen and Brian Toon of NASA-Ames. Modeling work has been carried out with the explicit microphysical model developed by Jensen and Toon. This work involved one-dimensional model experiments on the growth, evaporation and fall speeds of the kinds of small ice crystals which may be occurring in the upper troposphere of the Australian monsoon and less convectively active regions in the tropics. A central focus of this work has been the origin and persistence of thin subvisible tropical cirrus, a phenomenon occurring at the tropical tropopause for which there is a growing body of observational evidence. An important finding from this work is that the cold temperatures prevailing at the tropical tropopause allow the creation and days-long persistence of ice crystals small enough ($d < 10\ \mu m$) that their fall speeds become negligible on synoptic time scales. Dr. Selkirk is co-author on two recent papers on this topic.

Studies have been conducted of horizontal transport in the lower stratosphere using data from recent ER-2 and DC-8 field missions. In a number of cases, evidence was found for a clear trace constituent transition in subtropical latitudes between tropical and middle latitude air. During the transequatorial transit flights of the Airborne Southern Hemisphere Ozone Expedition and Measurements of the Atmospheric Effects of Stratospheric Aircraft (ASHOE-MAESA) airborne campaigns in 1994, the NASA ER-2 made two complete traverses of the tropical lower stratosphere. These flights have enabled a detailed investigation of the nature of the "subtropical boundary". This remains the subject of ongoing work using trajectory analysis and trace constituent correlations.

Dr. Selkirk also prepared trajectories for a study with Dr. Brian Toon on the temperature history of a polar stratospheric cloud (PSC) event observed by the NASA DC-8 during the 1992 Airborne Arctic Stratospheric Expedition (AASE-2). The results were published in the special AASE-2 issue of *Science*. For case studies from the Stratospheric Photochemistry, Aerosols and Dynamics Expedition (SPADE) and ASHOE-MAESA, Dr. Selkirk processed cloud and total ozone data for the GUMBO photochemical and dynamical model developed by a team of SPADE investigators.

Dr. Selkirk participated directly in and provided meteorological support for six field missions during the Cooperative Agreement. All of these have provided data for investigations under the Cooperative Agreement.

## Publications and Extended Meeting Abstracts

H. B. Selkirk, Changes in the thermal structure of the troposphere and lower stratosphere before and after monsoon onset 1987 over northern Australia. *Proceedings of the 19th Conference on Hurricanes and Tropical Meteorology, Miami, FL, 6–10 May 1991*, pp. 539-544, American Meteorological Society, Boston, MA.

H. B. Selkirk and E. J. Jensen, The persistence of very thin cirrus near the cold tropical tropopause. *Proceedings of the 11th International Conference on Clouds and Precipitation, Montreal, Quebec, 17-21 August, 1992*, pp. 522-524.

H. B. Selkirk, The tropopause cold trap in the Australian monsoon during STEP/AMEX 1987, *J. Geophys. Res.*, **98**, 8591-8610, 1993.

P. B. Russell, L. Pfister, and H. B. Selkirk, The Tropical Experiment of the Stratosphere-Troposphere Exchange Project (STEP): Science objectives, operations, and summary findings, *J. Geophys. Res.*, **98**, 8563-8590, 1993.

O. Toon., E. Browell, B. Gary, L. Lait, J. Livingston, P. Newman, R. Pueschel, P. Russell, M. Schoeberl, G. Toon, W. Traub, F. P. J. Valero, H. Selkirk and J. Jordan, Heterogeneous reaction probabilities, solubilities, and the physical state of cold volcanic aerosols, *Science,* **261**, 1136-1140, 1993.

## Meeting presentations

H. Selkirk and D. M. Winker, Pinatubo aerosol cloud edges in the subtropics: Evidence of sharp boundaries between the tropics and middle latitudes? Oral presentation to the Fall Meeting of the American Geophysical Union (AGU), San Francisco, CA, 7-11 December, 1992.

H. B. Selkirk, Horizontal variations of lower stratospheric trace constituents from the tropics to middle latitudes as revealed by aircraft measurements. Oral presentation to the Third Annual Meeting of the NASA Atmospheric Effects of Stratospheric Aircraft Project in Virginia Beach, VA, 7-10 June 1993.

E. Jensen, H. B. Selkirk, and O. B. Toon, On the formation and persistence of subvisible cirrus clouds at the tropical tropopause. Poster presentation at the Fall Meeting of the AGU, San Francisco, CA, 6-10 December, 1993.

H. B. Selkirk, On the relationship between subtropical jet streaks and tracer gradients. Oral presentation at the ASHOE-MAESA science team meeting in San Diego, CA, 3-7 April, 1995.

H. B. Selkirk, The development of a subtropical eddy in the upper troposphere and its relationship to tracer gradients in the stratosphere. Poster presentation at the annual meeting of the NASA Atmospheric Effects of Aviation Project in Virginia Beach, VA, 24-28 April 1995.

H. B. Selkirk, The subtropical surf zone and the 'inner tropics': Observations from the Pacific lower stratosphere during ASHOE-MAESA. Poster presentation at the quadrennial assembly of the International Union of Geodesy and Geophysics (IUGG) at the University of Colorado, Boulder, CO, 3-8 July 1995.

## Field mission support activities

1. Airborne Arctic Stratospheric Expedition (AASE-2), October 1991–March 1992. Potential vorticity forecasting for DC-8 flights.

2. Stratospheric Aerosol and Gas Experiment (SAGE-II) Pacific Survey Mission, May 1992. Mission meteorologist on NASA DC-8 at Ames and Tahiti.

3. Stratospheric Photochemistry, Aerosols and Dynamics Expedition (SPADE), October–November 1992, April–May 1993 and October 1993. Meteorological support of the NASA ER-2 at NASA-Ames.

4. Airborne Southern Hemisphere Ozone Expedition and Measurements of the Atmospheric Effects of Stratospheric Aircraft (ASHOE-MAESA), March–November 1994. Field meteorological and scientific support of the NASA ER-2 at Barbers Point, Hawaii and Christchurch, New Zealand, including provision of satellite imagery, tropical forecasting, processing of radiation data and support of the Ames Meteorological Measurements Systems (MMS) group.

5. Stratospheric Tracers of Atmospheric Transport (STRAT), May–June 1995 and October–November 1995. Field meteorological and scientific support of the NASA ER-2 at Ames Research Center, including provision of satellite imagery and surface weather forecasting.

6. Tropical Ozone Transport Experiment (TOTE), December 1995. Field meteorological and scientific support of the NASA DC-8 at Ames Research Center, Fairbanks, Alaska and Barbers Point, Hawaii, including provision of satellite imagery and surface weather forecasting.